Awareness Requirements for Adaptive Systems

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Adaptive Systems

- Growing interest (SEAMS, ICAC, SASO, ...);
- Feedback loop architectures [Andersson et al., 2009; Brun et al., 2009];
  - MAPE feedback loop [Kephart & Chess, 2003].

Adapted from [Hellerstein et al., 2004]
We know the requirements for this

... the objective ... is to make some output, say y, behave in a desired way by manipulating some input, say u ...” [Doyle et al., 1990]
GORE perspective

Based on [Jureta et al., 2008]
Adaptivity over Requirements

Target system requirement:
R = “Dispatch ambulance to emergency site”

Possible monitoring requirements for the controller:
R' = “Every execution of R succeeds / R never fails”
R'' = “R succeeds 95% of the time over any one-month period”

Awareness Requirements
Baseline

FLEA+KAOS [Feather98], ReqMon [Robinson06], ...

Schedule meetings

Vanilla RE

Dynamic analysis

Feedback

Plan

Making these requirements explicit
Awareness Requirements (AwReqs)

- Requirements that refer to other requirements and their success/failure at runtime;

- Outline:
  - Characterization / elicitation;
  - Formalization;
  - Validation (requirements monitoring);
  - A glimpse on System Identification;

- Agenda for the future:
  - Systematic process for modeling/design of AS;
  - Complete MAPE loop prototype.
Requirements as run-time objects

- AwReqs refer to the states that instances of requirements can assume at runtime;

Diagram:

- Undecided
- Succeeded
- Canceled
- Failed
Categories of AwReqs (1)

• Basic / regular / “never fail”:
  – *Input emergency information* should never fail;

• Aggregate (I):
  – *Communication networks working* should have 99% success rate;
  – *Ambulance arrives in 10 min* should succeed 60% of the time, while *Ambulance arrives in 15 min* should be successful 80%, measured daily;
Categories of AwReqs (2)

• Trend (D):
  - The success rate of *No unnecessary extra ambulances* for a month should not decrease, compared to the previous month, twice in a row;

• Delta (P):
  - *Update arrival at site* should be successfully executed within 10 minutes of *Inform driver*;
  - *Mark as unique or duplicate* should be decided in 5 min.
AwReq patterns*

- NeverFail(T-InputInfo);
- SuccessRate(D-CommNetsWork, 99%);
- @daily SuccessRate(Q-Amb10min, 60%) and SuccessRate(Q-Amb15min, 80%);
- not TrendDecrease(Q-NoExtraAmb, 30d, 2);
- ComparableDelta(T-UpdateArrSite, T-InfDriver, time, 10m);
- StateDelta(T-MarkUnique, Undecided, *, 5m).

* non exhaustive!

We could use qualitative values
Meta-AwReqs

• AwReqs that refer to other AwReqs;
  - AR3 = SuccessRate(G-SearchCallDB, 95%, 7d);
  - AR10 = SuccessRate(AR3, 75%, 30d).

• (Examples of) motivation:
  - Gradually enforcing compensations;
  - Avoid too many compensations.
Elicitation

Critical Ambulance Dispatching

AND

Increase available resources

Do more V & V

Model AwReqs for the ADS

From a talk by John Mylopoulos at University of Technology Sydney, Australia – Sep 28th, 2010
Elicitation

• After the elicitation of basic requirements;

• Some sources for AwReqs:
  - Critical or risky goals (high dependency, regulations, SLAs, safety);
  - NFRs (softgoals + quality constraints);
  - Preferable solutions in variation points (Update automatically should succeed 100 times more);
  - Trade-offs: R should fail between 5 and 10 times (failure lower bound).

AwReqs can operationalize contribution links!
Formalization

• Can use any language that:
  – Treats requirements as 1st class citizens;
  – Talks about their state in different time points.

• For our experiments, we chose OCL™ [Robinson, 2007];

• General approach:
  – Requirements represented as UML classes;
  – Execution at runtime = instance;
  – AwReqs written as OCL™ constraints.
Class model for requirements

DefineableRequirement
- time: Date
+ start(): void
+ end(): void
+ success(): void
+ fail(): void

Q-Amb10min extends this

T-InputInfo extends this

etc...
Formalization examples

**context** T–InputInfo

inv AR1: never(self.oclInState(Failed))

**context** G–SearchCallDB

def: all = G–SearchCallDB.allInstances()

def: week = all->select(g | new Date().difference(g.time, DAYS) <= 7)

def: success = week->select(d | d.oclInState(Succeeded))

inv AR3: always(success->size() / week->size() >= 0.95)
Experiment

• In a feedback loop, AwReqs relate directly to monitoring of requirements;
• There are some proposals for requirements monitoring, we adopted EEAT (ReqMon) [Robinson, 2006];
• OCL™ constraints are adapted to EEAT:

```plaintext
class T-InputInfo {
    def start : LTL::OclMessage = receivedMessage('start')
    def end : LTL::OclMessage = receivedMessage('end')
    def fail : LTL::OclMessage = receivedMessage('fail')

    inv AR1: between(start <> null, end <> null, never(fail <> null))
}
```
Experiment – How it works

**Target System** (e.g., ADS Java app)

*Input Emergency Information form*

Instrumented

Operator uses

**Other components of the controller**

**Feedback Loop Controller – Monitoring**

**T-InputInfo**

Instrumented

success()
fail()
...

EEAT log4j feed

CBE Log Events

**AwReqs (OCL™)**

**Drools rule engine**

Compile

**Property Events**

AwReq failure

**Other components** of the controller

**AwReq failure**
Experiment results

- AwReqs can be monitored;
- AwReqs can provide value for a feedback loop controller that implements adaptivity;
- Monitoring has little impact on the performance of the target system.
Conclusions – Our Contributions

- The definition of a new class of requirements that impose constraints on the run-time behavior of other requirements;
- Linguistic constructs for expressing and formalizing such requirements;
- Fragments of a prototype implementation founded on an existing requirements monitoring framework.
Current work – System Identification

Operationalized by AwReqs

- **Controlled parameters x Indicators:**
  - \( \text{NAA} = \text{Number of ambulances available}; \)
  - \( \text{S1} = \text{Success Rate of } \textit{Locate Available Ambulances}; \)
  - \( \Delta (\text{S1} / \text{NAA}) > 0 \)

- Submitted to ER 2011 (Under review)
Future work

- Complete MAPE loop:
  - Diagnosing, compensation, reconciliation;
  - Prototype framework;
  - CASE tools;

- For AwReqs:
  - Integration of domain models;
  - Addition of uncertainty factors (relaxed reqs.).
Thank You! Questions?

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AwReqs formalization – examples (2)

context T-InformDriver

\[\text{def: related : Set = T-UpdAtSite.allInstances() \rightarrow select(t | t.\text{arguments('callID')} = self.\text{arguments('callID')})}\]

\[\text{inv AR8: eventually(related\rightarrow size() == 1) and always(related\rightarrow forAll(t | t.oclInState(Succeeded) and t.time.difference(self.time, MINUTES) \leq 10))}\]

context T-MarkUnique

\[\text{inv AR9: eventually(not self.oclInState(Undecided)) and never(self.time.difference(self.startTime, MINUTES) > 5)}\]
Related work

• Goal-oriented, simpler approach;
  - No complex temporal constructs;
  - More suitable for requirements elicitation activities;

• Can be applied iteratively;

• Feedback loop-oriented;
  - We accept the fact that any of the requirements may eventually fail;

• Missing uncertainty factors;

• Not a full solution for adaptive systems yet.
Discussion – Full feedback loop

- EEAT OCL Compiler
- Rule File (Drools)
- Class Model (Java)
- Developer
- Goal Model (EMF)
- Monitored System (Instrumented)
- Log entries (CBE)
- Monitoring Server
- Callback
- AwReq Failure
- Diagnose Component
- Diagnosing Framework
- Reconcile Component
- Compensate Component
- Monitor Component
- OCL Message Events
- AwReqs (OCL™)
- Java Class Loader
- Requirements model and diagnosis
- AwReqs Framework
References

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